Heat-shock protein peptide complex–96 vaccination for recurrent glioblastoma: a phase II, single-arm trial

Orin Bloch, Courtney A. Crane, Yelena Fuks, Rajwant Kaur, Manish K. Aghi, Mitchel S. Berger, Nicholas A. Butowski, Susan M. Chang, Jennifer L. Clarke, Michael W. McDermott, Michael D. Prados, Andrew E. Sloan, Jeffrey N. Bruce, and Andrew T. Parsa

Department of Neurological Surgery, Feinberg School of Medicine, Northwestern University, Chicago, Illinois (O.B., R.K., A.T.P.); Department of Neurological Surgery, University of Washington, Seattle Children’s Research Institute, Seattle, Washington (C.A.C.); Department of Neurological Surgery, University of California–San Francisco, San Francisco, California (Y.F., M.K.A., M.S.B., N.A.B., S.M.C., J.L.C., M.W.M., M.D.P.); Brain Tumor and Neuro-Oncology Center, University Hospitals, Case Western Reserve University, Cleveland, Ohio (A.E.S.); Department of Neurological Surgery, Columbia University, New York, New York (J.N.B.)

Corresponding Author: Andrew T. Parsa, MD, PhD, Professor and Chair, Department of Neurological Surgery, Northwestern University, Feinberg School of Medicine, 676 N. St. Clair Street, Suite 2210, Chicago, IL 60611 (aparsa@nmff.org).

Background. Outcomes for patients with recurrent glioblastoma multiforme (GBM) are poor and may be improved by immunotherapy. We investigated the safety and efficacy of an autologous heat-shock protein peptide complex–96 (HSPPC-96) vaccine for patients with recurrent GBM.

Methods. In this open-label, single-arm, phase II study, adult patients with surgically resectable recurrent GBM were given vaccine after gross total resection. The primary endpoint was overall survival at 6 months. Secondary endpoints included overall survival, progression-free survival, safety, and immune profiling. Outcome analyses were performed in the intention-to-treat and efficacy populations.

Results. Between October 3, 2007 and October 24, 2011, 41 patients underwent gross total resection of recurrent GBM and received a median of 6 doses of HSPPC-96 vaccine. Following treatment, 90.2% of patients were alive at 6 months (95% confidence interval [CI]: 75.9–96.8) and 29.3% were alive at 12 months (95% CI: 16.6–45.7). Median overall survival was 42.6 weeks (95% CI: 34.7–50.5). Twenty-seven (66%) patients were lymphopenic prior to therapy, and patients with lymphocyte counts below the cohort median demonstrated decreased overall survival (hazard ratio: 4.0; 95% CI: 1.4–11.8; P = .012). There were no treatment-related deaths. There were 37 serious (grades 3–5) adverse events reported, with 17 attributable to surgical resection and a single grade 3 constitutional event related to the vaccine.

Conclusion. The HSPPC-96 vaccine is safe and warrants further study of efficacy for the treatment of recurrent GBM. Significant pretreatment lymphopenia may impact the outcomes of immunotherapy and deserves additional investigation.

Keywords: glioblastoma, heat-shock proteins, immunotherapy.
provided written informed consent prior to participation in the study. This was reviewed and approved by the institutional review board at each participating site. All patients provided written informed consent prior to receiving vaccine.

We previously studied the safety and efficacy of a heat-shock peptide protein complex–96 (HSPPC–96; Prophage) vaccine in a phase I trial for recurrent GBM. Our results demonstrated that the vaccine was well tolerated and resulted in a measurable systemic immune response to the patient’s specific tumor antigens. In the present study we evaluate the safety and efficacy of the HSPPC–96 vaccine in patients with recurrent GBM in a phase II, multicenter, clinical trial.

Materials and Methods

Patient Selection

In this single-arm, phase II trial, we enrolled participants from 3 centers in the United States. Individuals over the age of 18 were eligible for inclusion if they had histologically confirmed recurrent GBM after standard initial therapy. All participants were required to undergo surgical resection and have a postoperative Karnofsky performance status of at least 70% with a life expectancy >8 weeks. After surgical resection, all participants were screened to ensure an extent of resection >90% of the contrast-enhancing tumor prior to receiving vaccine.

Patients were excluded from study entry for known systemic autoimmune diseases, primary or secondary immunodeficiency, concurrent malignancy within the past 5 years (except carcinoma in situ of the uterus or cervix or nonmetastatic nonmelanoma skin cancer), a bleeding diathesis, uncontrolled active infection, or other serious unstable medical condition. Following surgical resection, patients were excluded for histologic diagnoses of pseudoprogression without recurrent tumor, incomplete surgical resection (<90% by volume), documented tumor growth (>10% increase in contrast enhancement) within 4 weeks of surgical resection at the first interval scan, or insufficient tumor to create at least four 25-μg doses of vaccine.

The protocol was submitted to the FDA (IND #12548) and approved by the institutional review board at each participating site. All patients provided written informed consent prior to participation in the study. This study is registered with ClinicalTrials.gov, NCT00293423.

Clinical Procedure

All patients underwent surgical resection and collection of their tumor intraoperatively for production of vaccine. Tumor tissue was freshly frozen and shipped to the manufacturing facility (Agenus) to generate vaccine in internalization of the HSP complex and cross-presentation of cleaved tumor peptides on major histocompatibility complex class I and II. By purifying HSP-96 protein complexes from a patient’s own tumor, a personalized polyvalent vaccine can be developed and administered for treatment.

Between October 3, 2007 and October 24, 2011, 68 patients with histopathologically proven recurrent GBM were screened and underwent surgical resection. One patient had less than a 90% extent of resection and 4 patients had a postoperative KPS <70% and were excluded. Of the remaining 63 patients, insufficient tumor was obtained to generate vaccine in 13. Of the 50 patients with sufficient tumor resected, 9 demonstrated disease progression or death if radiographic progression was not documented. We assessed adverse events using the Common Terminology Criteria for Adverse Events, version 4.0, from the National Cancer Institute. Preoperative blood samples drawn from all patients were analyzed by the clinical laboratory at each institution. A complete blood count with differential, including white blood cell count (WBC), absolute lymphocyte count (ALC), and absolute monocyte count (AMC), was obtained to evaluate pretreatment immune status.

Statistical Analysis

We tested the null hypothesis that 60% or fewer patients would survive at 6 months after surgery against the specific alternative hypothesis that 80% or greater would survive at 6 months. With a sample size of 38 patients, the null hypothesis would be rejected in favor of the alternative hypothesis if 27/38 (71%) or more patients were alive at 6 months, with a one-sided type I error of 0.10 and a power of 90%. A total accrual of 50 patients was planned for the phase I (previously reported) and phase II studies together.

Secondary analyses were performed to study OS and PFS for all patients. Survival curves for the intention-to-treat (ITT) and efficacy populations were generated using the Kaplan–Meier product-limit method. Peripheral immune function was assessed by evaluating leukocyte counts from preoperative blood draws. The distribution of each leukocyte count (WBC, ALC, AMC) was plotted and normality was tested using a Shapiro–Wilks test. If the factor was normally distributed, the median value was determined and patients were assigned to cohorts with values greater than or equal to or less than the median. Overall survival was compared between cohorts univariately using the log-rank test. Factors demonstrating significance in univariate analysis were tested in a multivariable Cox proportional hazards model with known predictors of outcome. Tests were accepted as statistically significant for 2-sided P values <.05. All statistical analyses were performed using SPSS (version 20).

Results

Between October 3, 2007 and October 24, 2011, 68 patients with histopathologically proven recurrent GBM were screened and underwent surgical resection. One patient had less than a 90% extent of resection and 4 patients had a postoperative KPS <70% and were excluded. Of the remaining 63 patients, insufficient tumor was obtained to generate vaccine in 13. Of the 50 patients with sufficient tumor resected, 9 demonstrated disease progression at the first follow-up prior to initial vaccination and were therefore excluded according to the study protocol.

Forty-one patients met all pre- and postoperative inclusion criteria and were assigned to receive the HSPPC–96 vaccine for recurrent GBM (Table 1). This group comprised the ITT population. The median time from surgery to first vaccination was 31 days (range, 23–55). Patients received a median of 6 vaccinations (range, 1–15), with 3 patients receiving less than the protocol minimum of 4 vaccinations. These 3 patients were included in the ITT population but excluded from the
efficacy population. Patients discontinued vaccination due to depletion of vaccine, tumor progression, withdrawal from the study, or investigator decision (Table 1). All patients were followed until death or closure of the data analysis on January 12, 2013. No patients were lost to follow-up.

At the time of final analysis, 39 patients (95%) had died. Two patients were alive without evidence of progression and were censored in the PFS and OS analysis. In the ITT population, the median PFS was 19.1 weeks (95% confidence interval [CI]: 14.1–24.1) with a 6-month PFS of 29.3% (95% CI: 16.6–45.7; Fig. 1A). The median OS was 42.6 weeks (95% CI: 34.7–50.5) with a 6-month OS of 90.2% (95% CI: 75.9–96.8) and a 12-month OS of 29.3% (95% CI: 16.6–45.7; Fig. 1B). The median PFS and OS were similar for the efficacy population (Supplemental Table S1).

In addition to clinical measures, preoperative blood samples were analyzed for leukocyte counts to assess immune function prior to treatment (Supplemental Table S2). The median ALC was 0.90 × 10^9 cells/L (range, 0.36–2.34), with 27 patients (66%) having an ALC less than the lower limit of normal (1.0 × 10^9 cells/L), according to the standard laboratory reference range. When OS was stratified by ALC, patients with an ALC greater than or equal to the median had significantly improved survival compared with patients with an ALC less than the median (49.1 vs 37.1 wk, P = .039; Fig. 2). The WBC and AMC were not predictive of outcome (Table 2). A proportional hazards model was constructed for OS including previously identified predictors of outcome (age, KPS), the number of vaccine doses received, and the ALC (Table 3). In this model, ALC was found to be an independent predictor of outcome with a hazard ratio of 4.0 (95% CI: 1.4–11.8; P = .012) for patients with an ALC below the median.

The number of vaccine doses given was also found to be significantly associated with outcome, with a hazard ratio of 0.85 (95% CI: 0.73–0.99; P = .036) per incremental dose. This association was expected, as patients with longer PFS were eligible to receive more vaccine doses. A post hoc analysis of survival grouped by reason for discontinuation of vaccine was performed to compare outcomes between patients who progressed on vaccine and those who received all eligible doses (Supplemental Table S3). Patients progressing on vaccine expectedly had a shorter PFS (Supplemental Fig. S1), but OS and survival from progression were also significantly shorter compared with patients completing treatment (P < .001; Supplemental Fig. S2).

Table 1. Characteristics of patients receiving HSPPC-96 vaccine

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>55 (21–75)</td>
</tr>
<tr>
<td>≤40</td>
<td>3 (7%)</td>
</tr>
<tr>
<td>41–50</td>
<td>10 (24%)</td>
</tr>
<tr>
<td>51–60</td>
<td>11 (27%)</td>
</tr>
<tr>
<td>61–70</td>
<td>15 (37%)</td>
</tr>
<tr>
<td>&gt;70</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>30 (73%)</td>
</tr>
<tr>
<td>Female</td>
<td>11 (27%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>39 (95%)</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Karnofsky performance score</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>15 (37%)</td>
</tr>
<tr>
<td>80</td>
<td>20 (49%)</td>
</tr>
<tr>
<td>70</td>
<td>6 (14%)</td>
</tr>
<tr>
<td>Time from diagnosis to progression, wk</td>
<td>35</td>
</tr>
<tr>
<td>Median</td>
<td>11–321</td>
</tr>
<tr>
<td>Time from surgery to first dose of vaccine, days</td>
<td>31</td>
</tr>
<tr>
<td>Median</td>
<td>23–55</td>
</tr>
<tr>
<td>Number of vaccine doses administered</td>
<td>6</td>
</tr>
<tr>
<td>Median</td>
<td>1–15</td>
</tr>
<tr>
<td>Reason for vaccine discontinuation</td>
<td></td>
</tr>
<tr>
<td>Progression</td>
<td>21 (51%)</td>
</tr>
<tr>
<td>Vaccine depleted</td>
<td>13 (32%)</td>
</tr>
<tr>
<td>Patient withdrew</td>
<td>5 (12%)</td>
</tr>
<tr>
<td>Investigator decision</td>
<td>2 (5%)</td>
</tr>
</tbody>
</table>

Fig. 1. (A) Kaplan–Meier estimates of PFS in 41 patients receiving the HSPPC-96 vaccine for recurrent GBM. Vertical lines indicate the timepoints at which patients were censored. (B) Kaplan–Meier estimates of OS in 41 patients receiving the HSPPC-96 vaccine for recurrent GBM. Vertical lines indicate the timepoints at which patients were censored.
A summary of all adverse events recorded during the study period is reported in Table 4. The toxicity associated with the vaccine was minimal, related primarily to injection site reactions. A single patient experienced grade 3 fatigue possibly related to vaccine. There were no grade 4 adverse events or deaths attributable to the vaccine. Seventeen serious adverse events (grades 3–4) were associated with surgical resection consistent with the known risks of a craniotomy for GBM.\textsuperscript{18} There was a single death associated with development of a delayed subdural hematoma in the setting of thrombocytopenia. This occurred 6 months after the tumor resection and was unrelated to vaccine administration.

**Table 2.** Overall survival stratified by immune markers in vaccine patients

<table>
<thead>
<tr>
<th>Marker</th>
<th>Median OS (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>White blood count</td>
<td>37.1 (5.8 – 25.8)</td>
<td>46.7 (39.6 – 53.8)</td>
</tr>
<tr>
<td>Absolute lymphocyte</td>
<td>49.1 (38.0 – 60.3)</td>
<td>37.1 (26.4 – 47.9)</td>
</tr>
<tr>
<td>Absolute monocyte</td>
<td>40.9 (29.1 – 52.6)</td>
<td>43.0 (36.1 – 49.9)</td>
</tr>
</tbody>
</table>

**Discussion**

There is no currently accepted standard of care for the management of recurrent GBM. Repeat surgical resection is often performed, supported by a number of retrospective studies suggesting that increased cytoreduction through gross total resection at recurrence results in improved survival.\textsuperscript{19–21} Bevacizumab has gained wide acceptance as the first-line therapy for recurrent disease based on a number of phase II studies demonstrating a median PFS of 11–24 weeks and median OS of 26–44 weeks.\textsuperscript{10–13,22} Numerous other chemo therapies have been tested in phase II clinical trials for recurrent GBM with a range of median PFS of 9.6–17 weeks and median OS of 21–41 weeks.\textsuperscript{6–9,23,24} In 2011, Clarke and colleagues\textsuperscript{25} published a systematic analysis of the results of all North American Brain Tumor Consortium phase II trials for recurrent GBM from 1998 to 2008, demonstrating an aggregate median PFS of 9.3 weeks and median OS of 33.1 weeks. A
similar analysis of the European experience between 1999 and 2010 from pooled phase I and II trials from the European Organisation for Research and Treatment of Cancer Brain Tumor Group demonstrated a median PFS of 7.2 weeks and median OS of 24.8 weeks.26

Immunotherapy for GBM promises to improve outcomes for patients by providing a highly specific, nontoxic alternative to conventional chemotherapy. To date, the immunotherapy approaches applied clinically to recurrent GBM have utilized an active vaccination approach with or without an immune-boosting adjuvant. Patients have been vaccinated with tumor-specific peptides conjugated to immunoadjuvants or with autologous dendritic cells cultured and pulsed with tumor peptides ex vivo, with reported median PFS rates of 8–20 weeks and median OS rates of 40–46 weeks.27–29 Here, we report on the use of an HSP-based vaccine for the treatment of recurrent GBM. We previously reported our phase I results, including immune-monitoring data that confirmed a vaccine-specific peripheral immune response in 11/12 patients.16

In the present study we demonstrate a median OS of 42.6 weeks, with 90.2% of patients surviving longer than 6 months. As this study is a single-arm, uncontrolled trial, the outcomes can only be compared with historical controls from similar trials. It is important to note that the patients in this trial represent a highly selected group who may be expected to have better outcomes. As determined by the study design, all patients receiving vaccine underwent a gross total surgical resection and had good functional status prior to vaccination. Therefore, the results of the current trial are most appropriately compared with other surgically based clinical trials for recurrent GBM with similar enrollment criteria. In the original phase III trial supporting the use of carmustine impregnated implantable wafers, Brem and colleagues5 reported a 6-month OS of 56% for patients receiving the carmustine implants versus 36% for patients receiving a placebo implant at resection. They reported >75% extent of resection in over 85% of their patients, with a median OS for the carmustine treatment group of 31 weeks. More recently, Kunwar and colleagues36 studied the efficacy of a chimeric IL-13 to pseudomonas exotoxin fusion protein (IL13-PE38QQR, Cintredekin besudotox) delivered by convection-enhanced delivery following resection of recurrent GBM, compared with patients receiving carmustine impregnated wafer implantation at resection (PRECISE Trial).37 Patients enrolled in this trial had a median age of 55 years, KPS ≥ 70%, and gross total surgical resection. The authors reported no significant difference in outcomes between treatment groups, with a median OS of 36.4 weeks in the cytotoxin group compared with 35.3 weeks in the carmustine wafer group.36 Relative to the outcomes of these comparable, large, surgically based trials for recurrent GBM, the outcomes from HSPPC-96 vaccination appear promising. The survival results of the current study are also comparable to the best outcomes reported with bevacizumab. Admittedly, many patients receiving bevacizumab in these trials did not undergo prior repeat surgical resection. A proper comparison of the efficacy of HSPPC-96 vaccination with bevacizumab would require equivalent surgical resection in both groups. We believe the findings in the current study support the value of a comparison between the HSPPC-96 vaccine and bevacizumab in surgically accessible recurrent tumors. A 3-arm, randomized phase II clinical trial comparing vaccine to vaccine in combination with bevacizumab to bevacizumab alone following surgical resection is now open and has begun enrolling patients (NCT01814813).

In addition to evaluating standard clinical endpoints, we studied the impact of immunologic status on patient outcomes. Systemic immunosuppression is a well-recognized finding in patients with GBM.31–33 A number of mechanisms have been identified to account for this immunosuppression, including tumor-induced lymphopenia, expansion of regulatory T cells, and expansion of immunosuppressive monocytes/macrophages.34–37 To study the impact of immune status on the efficacy of the HSPPC-96 vaccine, we measured preoperative leukocyte fractions including WBC, ALC, and AMC. The majority of patients were found to be lymphopenic, with those patients having less than the median ALC demonstrating significantly decreased OS in univariate and multivariate analysis. Although it is not surprising that lymphopenia can decrease the efficacy of immunotherapy meant to induce a cytotoxic lymphocytic response, there are few reports correlating pretherapeutic immune status with outcome in phase II or III clinical trials of immunotherapy for GBM. Our findings suggest that patients may benefit from adjuvants to address tumor-induced lymphopenia, and the implications of pretreatment lymphopenia warrant consideration when selecting patients in future tumor vaccine clinical trials.

Supplementary Material
Supplementary material is available online at Neuro-Oncology (http://neuro-oncology.oxfordjournals.org/).

Funding
This work was supported by the National Cancer Institute Special Program of Research Excellence (SPORE); American Brain Tumor Association; National Brain Tumor Society; and the Accelerated Brain Cancer Cure, Inc. Dr. Bloch is partially supported by the Reza and Georgianna Khatib Endowed Professorship in Neurological Surgery. Dr. Parsa is partially supported by the Michael J. Marchese Endowed Chair in Neurological Surgery.

Conflict of interest statement. None declared.

References


